MINI-SYMPOSIUM: REVISION HIP ARTHROPLASTY

(i) International epidemiology of revision THR

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Summary
The worldwide number of primary total hip replacements has increased over the last decade, and as the number of primary total hip arthroplasties (THAs) increases each year, the number of revision THAs can also be expected to increase. Revision THAs often lead to suboptimal results, more complications and high costs. The rapid growth of new surgical techniques and new hip implants warrants a continuous and objective monitoring of the results to lower revision rates and improve outcomes. From an international standpoint, the revision burden is one of the possible key figures that allow crude comparisons between different countries and health systems. Evidence based information and revision rates can be derived from national joint registry data. In countries without registries, data can be collected from large data sets used for billing, national hospital discharge surveys and quality surveys. In addition single- and multicentre data regarding revision THA in combination with randomised control trials (RCTs) can be used. However, certain strengths and weaknesses apply to non-registry data sources which will be discussed. It was shown that the overall revision burden which is as high as 17.5% in some countries, could be improved in countries with national joint registries. One way to lower revision rates in the future is to use evidence-based primary implants. Registry data have the power to identify such implants, surgical techniques and processes. Thus it can guide surgeons in an evidence-based fashion to the benefit of patient outcome.

Introduction
Total joint arthroplasty (THA) surgery is widely recognised as one of the most cost-effective interventions in medicine today. The number of both primary and revision surgeries increased steadily over the last decade, and as the number of primary arthroplasties increases each year, the number of revisions can also be expected to increase. For the US a rise of 137% over the next 25 years is estimated for revision THAs. Complications and multiple revisions often lead to suboptimal results and high costs. Costs are as high as $15,000 to $30,000 per revision. From an international standpoint, the revision burden is one of the possible key figures that will enable basic comparison between different countries and health systems. Despite continuous improvements in implant technology, the revision burden—defined as the ratio of revision to the total number of arthroplasties—has remained relatively constant in the US.
Worldwide there are different data sources available that are used to calculate crude annual revision rates. Non-registry data sources include large data sets used for billing, national hospital discharge surveys (NHDSs) and quality surveys. In addition, single and multicentre data combined with randomised control trials (RCTs) can provide data regarding revision THA. In general different inclusion and exclusion criteria influence the power of these data sets. Also, many national reports regarding the results of total hip replacements are based on series from centres with a high annual volume of such procedures. Katz demonstrated, that outcome for low volume centres, however were worse than at high volume centres with higher revision rates.

More comprehensive information regarding patient characteristics, prosthesis type and features, method of prosthesis fixation and surgical technique, however can be derived from national joint registries. Although there might be differences in the inclusion criteria such as age, end point definition or inclusion of late complications, registries provide high quality, evidence-based data. Many countries have used joint registries for several years. Other countries recently have started or are in the planning phase. The validity of these data is persistently improving. Computer network technologies enable doctors and medical staff to enter data on line and to make adjustments e.g. for death as it is done in Sweden. These prospectively collected data are more accurate compared to previous reports which were collected retrospectively on large billing data sets requiring the use of assumptions and estimates. The improved failure definitions and accuracy in the epidemiological data will also facilitate comparisons and benchmarking among different national registries. However, there is a time gap until valid data regarding survival and revision surgery (type, percentage, etc.) can be gathered from new registries.

The rapid growth of both new surgical techniques (i.e. minimally invasive hip arthroplasty) and new hip implant technology highlight the need for a continuous and objective monitoring of the results (post-market surveillance) plus means to distribute these data to key stakeholders. Despite rigorous testing prior to introduction of new devices, examples of early failures exist and therefore systems which allow for identification of premature failure benefit physicians, health systems and patients.

Since the expenditure for total joint replacements is increasing in many countries over the last years, also from a financial standpoint it is more and more important to gather data regarding surgical outcome, indications for joint replacements, types of prostheses and techniques. The purpose of this manuscript is to discuss strengths and weaknesses from data regarding the epidemiology of revision THAs derived from different international data sources.

**Data collection—sources of data**

Worldwide there are different existing data sources that can be used to calculate or estimate crude annual revision rates. The ratio of revision to the total number of arthroplasties (revision burden) gathered longitudinally is a general indicator of expected longevity of total hip replacements. If more specific information regarding type of fixation, implant design etc. is added to the data, more accurate information (e.g. survivorship of certain implants) can be derived. In addition, there are often different inclusion criteria such as age, end point definition or inclusion of late complications. These might increase or decrease the meaning of the results. In the following the strengths and weaknesses of different data collection methods such as large data sets used for billing, single centre data, RCT and national registries are listed.

**Large data sets**

From countries where national registries are not yet implemented, data can be derived from other sources (i.e. billing data sets, NHDSs, national quality surveys), but this information has many problems (i.e. poor documentation of primary versus revisions, side, implant type). In a study performed by Kurtz, data was derived from the NHDS in the United States. It is an annual survey conducted by the National Center for Health Statistics. Started in 1965, this survey programme has continuously compiled a representative sample of hospitalisations at non-federal and non-military short-stay community hospitals throughout the United States. Information collected by the NHDS includes patient demographics (e.g. age and gender), disease diagnosis, type of procedure performed, institutional characteristics, and resource utilisation. On the basis of the information collected by the survey and with use of the provided sampling weights, national and regional estimates of characteristics of patients and of surgical and non-surgical procedures in hospitals with various numbers of beds and types of ownership can be estimated. In Germany, a national hospital quality survey has been carried out over the last years. It is thought to identify hospitals with unusually high complication rates and to discuss reasons for that. Also crude revision burden can be derived from this database. However two-stage revisions, late complications or implant related problems after the initial hospital stay are not or only partially recorded.

**Single centre data**

Most reports of the results of THAs are based on series from centres with a high annual volume of such procedures, whereas the outcomes in low volume centres have received little study. Both greater hospital volume and greater surgeon volume have been associated with lower rates of mortality and/or complications following several surgical procedures. It has been shown by Katz, that a higher volume surgeon was significantly associated with a lower rate of dislocation (P value for trend = 0.0001 and, slightly less strongly with a lower rate of deep infection P = 0.03). Patients who had primary THAs in hospitals where more than 100 of these procedures were performed per year had a lower rate of mortality than those who had primary replacement in hospitals in which 10 or 20 procedures were performed per year (mortality rate 0.7% compared with 1.3%). These analyses of Medicare claims are limited by a lack of key clinical information such as preoperative comorbidity, functional status and operative details. Nevertheless, it is likely that single centre data would reveal more...
biased results in terms of stating lower complication and revision rates as opposed to low volume community centres.

**Randomised control trials (RCTs)**

In general randomised blinded control trials provide excellent data compared to retrospective studies with historical controls. Potential advantages of RCTs are the unbiased distribution of confounders and the statistical design of these studies (Level 1 evidence). However, these studies are expensive in terms of time consumption and money and ethically problems do sometimes arise. Since studies are likely to be carried out in high volume centres with experienced surgeons who have relatively low revision rates, the results do not necessarily reflect the nationwide surgical practise and are limited by nature to a small number of different fixation techniques and implant designs.

**National registries**

National joint registries define the epidemiology of primary and revision surgery. The primary reason to document failures is to improve and redefine the primary indication, surgical technique and implant choice. It is thought that feedback of data stimulates the participating clinics to reflect and improve their health care accordingly (i.e. The Quality Cycle). Traditionally, revision THA has been used as an end point definition. In the future, however, patient based outcome measures and radiographic results are thought to improve sensitivity. In conjunction with individual, subjective, patient data and radiography, joint replacement registries contribute to the development of evidence-based THA.

Many countries have utilised national joint replacement registries for several years (Australia, Canada, Denmark, Finland, Hungary, Norway, New Zealand, Sweden and Romania). Other countries have recently started or are in the planning phase of developing national joint replacement registries (Austria, Czech Republic, England, France, Germany, Moldova, Slovakia, Turkey, USA and Wales). In contrast, the Swedish hip register contains information on primary hip arthroplasties performed in Sweden since 1979. This information source has led to a stepwise reduction in annual crude revision rates, improvements in surgical centre performance and early removal of poorly functioning implants from use. In the 2003 report from the Swedish total hip joint register, the results were based on data for each primary procedure, captured since 1992, and adjustment for death was made on line, which was considered to be a major improvement compared with previous reports where part of the statistics were based on assumptions and estimates. The improved failure definitions and accuracy in the epidemiological data will also facilitate comparisons and benchmarking among different national registries.

**Registry data**

So far a true comparison of crude revision rates from different countries is not possible without considerable bias. Even countries with established joint registries do have different types of data collection and inclusion criteria (i.e. some are age-standardised, others not; some include population <20 years, others do not). The following data, are derived from national joint registries, alternate equivalent sources and from different years to give an overview (Table 1). In general the revision burden is considered as the proportion of hip replacements that were revisions. In Sweden, results are based on more than 90% all cemented THA. The revision burden for cemented implants is considerably lower than for uncemented implants (28.1% less 1992–2003) and even hybrid combinations (10.8% less 1992–2003). This is probably related to inferior acetabular fixation and polyethylene quality of the uncemented implants used in Sweden.

As outlined before, data regarding the annual revision burden in the United States was calculated from the NHDs. Data were stratified by age and gender. Overall, when all data that were collected over the 13-year period were considered, a mean revision burden for THA of 17.5% (annual range 15.2–20.5%) was found for the period from 1990 to 2002. All patients regardless of age and gender were included in these data.

**Reasons for revisions**

Calculated from the Swedish registry, revision was the dominant subsequent procedure, accounting for 86% of all re-operations. The most common reason for revision surgery in this data pool was aseptic loosening (73.9%), followed by deep infection (7.9%), dislocation (7.5%) and periprosthetic fractures (5.7%). These data were similar in comparison to other countries (Australia, England/Wales). Although the true impact of joint registries is not exactly known, the rate of overall implant survival (including poor designs) has improved in Sweden from 89.4% to 92.5% between the two periods 1979–1991 and 1992–2003. Patients with index diagnoses of rheumatoid joint disease and sequel to childhood hip disease are overrepresented in the group of multiple revisions as are those revised due to deep infection, periprosthetic fractures and dislocation.

**Aseptic loosening trends**

In general the quality has improved in terms of fewer revisions because of aseptic loosening in Sweden. For

<table>
<thead>
<tr>
<th>Country (year)</th>
<th>Revisions (%)</th>
</tr>
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<tbody>
<tr>
<td>Australia (2003–2004)</td>
<td>13.4</td>
</tr>
<tr>
<td>Canada (2003–2004)</td>
<td>9.0</td>
</tr>
<tr>
<td>Denmark (1998)</td>
<td>14.5</td>
</tr>
<tr>
<td>Germany (2004)</td>
<td>11.4</td>
</tr>
<tr>
<td>Norway (2001)</td>
<td>13.0</td>
</tr>
<tr>
<td>New Zealand (2004)</td>
<td>13.0</td>
</tr>
<tr>
<td>Sweden (1992–2003)</td>
<td>9.9</td>
</tr>
<tr>
<td>United States (1990–2002)</td>
<td>17.5</td>
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</table>
cemented implants the results for the stem are generally better than the cup, with the flanged Charnley cup as the sole exception. In uncemented and hybrid implants, the stem results are generally good, whereas the cups show poorer results. This is in accordance with data from England, where cup revisions were more common than single stem revisions.

Infection trends

One major contributor to revision surgery is prosthetic infection with an incidence of 0.2–4%. Resistance to antibiotics is a problem, too. It could be shown from the Norwegian arthroplasty register that an operating time of more than 150 min was associated with an increased risk of revision due to infection. In case of infection, it has been observed that the rate of recurrent infection is higher after one stage revision as opposed to two stage revision. An investigation, performed in Sweden and the Netherlands, 864 revisions were performed for deep infection. A total of 245 were one-stage revisions, 455 were two-stage revisions and 164 ended up in permanent extractions. The average time in between stages was 115 days in Sweden. There were initially 93% cemented (27% with antibiotics), 2% uncemented and 5% hybrid THAs. There was a significant difference between one-stage versus two-stage revisions. Re-revision had to be performed in 29 (11.8%) of one-stage patients and in 33 (7.3%) of two-stage patients ($\chi^2$: $P<0.03$).

Thus, two stage revisions had a higher success rate in terms of eradication of infection. The risk for infection also was increased without the use of antibiotic bone cement and in male patients.

Dislocation trends

In Sweden, there is currently an increase of revisions due to dislocation and or technical reasons. For patients with 5 years follow up the cumulative revision rate is five to six times higher for the group operated on in 1998 compared to those operated on in 1984. This might be related to an increase in primary THA for displaced cervical femoral fractures in the elderly, which is in contrast to a long tradition of using percutaneous techniques with screws or pins as the primary intervention. Another explanation is the equally long tradition in Sweden with use of small head sizes (22 or 28 mm). The overall dislocation rate after revision THA in Germany is relatively low (2.7%, range 0.0–19.0%). However, in these data only early dislocations are recorded. Late complications after the initial hospital stay are not or only partially recorded. The implementation of a national joint registry collecting long-term data is planned, however, not before the year 2008 (pers. communication Dr. Boy).

Volume effects on outcomes of revision THA

In the United States, the number of primary total hip replacements increased from 119,000 in 1990 to 193,000 in 2002, calculated from NHDS data. For this time period, a mean revision burden of 17.5% (range 15.2–20.5%) has been reported. Patients treated at hospitals and by surgeons with higher annual caseloads of primary and revision THA had lower rates of mortality and of selected complications. It is estimated that the cost of a routine revision THA was approximately $18,000. For a complex revision, the cost goes up to as high as $30,000. If the 2002 hip revision burden of 18.1% was reduced by 1% (a decrease of approximately 2844 hip revision procedures), the potential cost savings could range from $42.5 million to $112.6 million.

Components utilised trends

Over the last years, in some countries (e.g. Australia, Denmark), there is a trend to uncemented implants. Other countries predominantly use cemented fixation such England and Sweden, where 95% of the hip arthroplasties are cemented. In England, there is also an increasing trend to resurfacing in the group of patients <55 years. The high percentage of cemented implants in Sweden as opposed to other countries may be one reason for the comparatively lower revision rate, since a higher revision rate has been reported with first generation uncemented designs. Another reason for a lower revision rate in Sweden might be a positive effect on surgical quality, promoted many active years’ use of the national hip register.

Epidemiology of components revised

It is interesting to identify which components are being revised in revision THA. In England for example, more than 50% of revisions were of both femoral and acetabular components. However in those cases where only the stem or only the cup was revised, isolated cup revisions were done more often then single stem revisions (Table 2). The same trend applies for Australia, whereas the total number of stem and cup revisions is lower.

Registry data demonstrate that the survivorship of implants in revision THA is less than in primary THA. In Norway, data (1987–2003) demonstrated a 26% failure rate at 10 years in 4762 revision THAs when infection was excluded as a cause for revision.

Table 2 Percentage of revision hip surgery procedures in England and Australia.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Australia (%)</th>
<th>England (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral head alone</td>
<td>21.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Femoral stem alone</td>
<td>37.4</td>
<td>15.9</td>
</tr>
<tr>
<td>Acetabular cup or shell ± liner ± femoral head</td>
<td>37.6</td>
<td>53.7</td>
</tr>
<tr>
<td>Acetabular cup or shell ± liner and femoral stem ± femoral head</td>
<td>4.0</td>
<td>4.7</td>
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Conclusions

The overall aims of a national joint replacement register is to pool data, recognise trends, improve the quality of THA and promote evidence-based surgical practise. The register can generate hypotheses suitable for either specific studies based on registry data or carefully planned prospective clinical studies. The failure end-point definition used in registries has traditionally been revision.

The overall rate of complications and the need for revision total hip arthroplasty is influenced by the volume of cases performed at hospitals and by surgeons.\textsuperscript{2,20}

It is important to clearly define and internationally agree on which key features should be presented in national registers in order to make comparisons unbiased. Different countries often have different perspectives (i.e. whether to use cemented or non-cemented stems) making comparisons difficult. An international Register Society could facilitate this process and there are ongoing efforts to initiate this.\textsuperscript{4}

Perspectives/trends

* Data derived from national joint registries is advantageous as opposed to data derived from large data sets and or single centre data.
* Registry data can contribute to lower revision rates. In Sweden, the proportion revised for the most common complication (aseptic loosening) has decreased to one third.
* The rate of implant survival might improve through the use of registry data. For example, the rate of implant survival has improved from 89.4% to 92.5% between the two periods 1979–1991 and 1992–2003 in Sweden.
* The rate of mortality and selected complications in high volume centres is lower as compared to low volume centres in the US.
* It is important to lower revision rates nationwide for the number of joint replacements is steadily increasing, so is the revision rate. As calculated for the United States, the number of THAs will increase 137% from 2005 to 2030.
* To meet future needs nationwide usage of joint registries and data evaluation might be a strong factor to identify potential sources for failure and to further lower revision rates.

References